Triple scattering of electrons

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SUMMARY

In this thesis scattering experiments of relativistic electrons from heavy atoms are described. The main attention is given to a new type of experiments in which electrostatically accelerated electrons experience three subsequent scattering events on gold targets.
A justification for this type of so-called triple scattering experiment may be found in the Introduction (Chapter I) and in Chapter II, section 2.

In Chapter II a cursory description of the theory of electron scattering is given, the main purpose being the definition of the various parameters in electron scattering and the description of the relation of our experiments to other experiments in this field, i.e. double scattering experiments and measurements of the differential cross-section. The last part of Chapter II contains a short review of the present situation of theory and experiment, which reveals the existence of some unsolved discrepancies.

The question whether or not triple scattering experiments are feasible depends on the solution of the intensity problem. Therefore, we have critically evaluated the various methods for producing polarized electrons in order to find the best way to

obtain an intensive highly polarized beam. This evaluation is reported in the first section of Chapter III. As it turns out, large angle scattering of accelerated electrons is best suited to our purpose. The second section of Chapter III contains a detailed description of the apparatus used to produce a polarized electron beam. An essential improvement of the overall performance of the original electron accelerator was achieved by installing a magnetic quadrupole doublet, which focuses the electrons on the first scatterer (3.2.1). This quadrupole doublet was designed in collaboration with R.S.de Vries, who also improved the performance of the electron gun, leading to an enhancement of the available beam current.

By the first scattering, over 105°, a transversely polarized beam is produced,which - for 261 keV electrons - has an intensity of 1.5 nA and a degree of polarization of 0.30. The polarization vector after this scattering has a vertical orientation, which, for instrumental reasons, must be transformed to a horizontal one. To perform this transformation we developed a method - already envisaged by Dr. Van Klinken - to rotate the spin in a longitudinal magnetic field which simultaneously focuses the electrons on the second scatterer (3.2.2).

An electrostatic spherical deflector may be used to convert the transverse polarization - as obtained by scattering - to a longitudinal one (3.2.3). The electrostatic deflector was designed with the help of J.W.G.Aalders and D.H.Homan. The latter also designed an electrostatic quadrupole doublet which may be used to compensate for the rather infavourable focusing characteristics of the deflector.

A detailed account of the triple scattering experiments is given in Chapter IV. In the first section a description of the Mott analyser, of the experimental conditions in the second scattering and of the electronics and automation is given, while section 4.2 contains a description of the experiments, the data reduction and the results. These results are obtained by performing asymmetry measurements at various azimuthal orientations of the plane of the Mott analyser with respect to the plane of the second scattering. Each asymmetry measurement at a certain azimuthal angle ϕ consists of ten to fifteen pairs of individual runs with alternating counter positions. From (typically) ten asymmetry measurements the magnitude and the direction of the transverse component of the polarization vector is deduced. Triple scattering experiments are alternated with measurements of the initial polarization.

The results of the experiments at an electron energy of 261 keV - obtained in collaboration with J.W.G. Aalders - deviated somewhat from the then available theoretical predictions, which prompted us to start another series of triple scattering experiments at a different energy (46 keV). Meanwhile, new theoretical results became available slightly enlarging the discrepancies for the results of both experiments.

The experimental results for the triple scattering parameter F - defined in terms of the scattering amplitudes f and g and the scattering angle θ as

$$F = \frac{fg^{\times} + gf^{\times}}{ff^{\times} + gg^{\times}} \sin\theta + \frac{ff^{\times} - gg^{\times}}{ff^{\times} + gg^{\times}} \cos\theta$$

- are summarized in the table together with the most recent theoretical predictions[1] for scattering on gold:

Results for F

Scattering angle θ	261 keV		46 keV	
	Exp.	Theory	Exp.	Theory
45°	0.85 ± 0.03	0.916	0.96 ± 0.02	0.791
75°	0.69 ± 0.02	0.777	0.64 ± 0.03	0.565
101°	0.45 ± 0.03	0.508	0.27 ± 0.02	0.128

The deviations cannot be explained as a result of the systematic errors discussed in section 4.3.

Mendels and Wouthuysen[2] have recently questioned the very basis of Dirac theory . In particular they suggest that it would be possible to conceive a theory in which parity would not be conserved for the interaction of relativistic fermions with electromagnetic fields. This suggestion inspired the decision to perform a new experiment - in collaboration with D.H.Homan - to test the presence of the suggested non-conservation of parity by investigating the longitudinal polarization of electrons after interaction with macroscopic as well as microscopic fields. The results of these experiments, given in Chapter V, yield an upper limit for the degree of longitudinal polarization which excludes the suggested parity violation as a cause of the discrepancies.

In principle, the apparatus described in this thesis is also suited for a triple scattering experiment with a longitudinally polarized beam incident on the second scatterer. In view of the results described, it would be worth-while to perform such an experiment.

References

1. W.Bühring, private communication; Z. Phys. 212 (1968) 61.
2. E.Mendels and S.A.Wouthuysen, Proc. Kon. Acad. Wetensch. B71 (1968) 342.

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